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Cross-correlation markers in stochastic dynamics of complex systems

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ABSTRACT

The neuromagnetic activity (magnetoencephalogram, MEG) from healthy human brain and from an epileptic patient against chromatic flickering stimuli has been earlier analyzed on the basis of a memory functions formalism (MFF). Information measures of memory as well as relaxation parameters revealed high individuality and unique features in the neuromagnetic brain responses of each subject. The current paper demonstrates new capabilities of MFF by studying cross-correlations between MEG signals obtained from multiple and distant brain regions. It is shown that the MEG signals of healthy subjects are characterized by well-defined effects of frequency synchronization and at the same time by the domination of low-frequency processes. On the contrary, the MEG of a patient is characterized by a sharp abnormality of frequency synchronization, and also by prevalence of high-frequency quasi-periodic processes. Modification of synchronization effects and dynamics of cross-correlations offer a promising method of detecting pathological abnormalities in brain responses.

1. Introduction. Synchronization and collective effects in time series analysis of complex systems

One of the main factors determining the evolution of complex systems is the presence of collective effects arising from an interacting or redistributing of the certain connections between parts of a composite system. In many cases it is impossible to make an adequate analysis of the functioning of such systems by ignoring the underlying collaborative mechanisms.

There are various approaches used in studying the collective phenomena in complex systems. Somehow or other, all of them are based on the analyzing unique features of the connected systems: certain quantitative and qualitative ratios between the system elements, a dynamic coordination of components under the external influences, specific synchronization phenomena. Some recent results have been derived by studying the effects of frequency and phase synchronization [1–5]. These methods are based on revealing the characteristic frequencies and analyzing the differences in the phases of dynamic variables derived by means of the Fourier transform, Hilbert transform [1,2,4] and wavelet-transform [5]. Within the framework of another methodology the stochastic synchronization is studied by comparing topological structures of attractors, describing the dynamics of two nonlinear coupled oscillators [6]. The "generalized synchronization" relationship [7] also uses the topological method and is the successful original development of the stochastic synchronization approach.

Another approach to study the collective effects in complex systems is the analysis of cross-correlations, i.e. the probabilistic relation between the sequences of random variables. The cross-correlation method is used to describe the collective phenomena in various systems (physical, economical, biological and physiological). The perspective approach in

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